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TECHNICAL REPORT
NATICK/TR-93/010

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DATA ACQUISITION SYSTEM FOR ANALYSIS OF BURN INJURIES FROM FLAME AND THERMAL RADIATION

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December 1992

Final Report
October 1990 - September 1992

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REPORT DOCUMENTATION PAGE

Form Approved
OMB No 0704-0188

1. AGENCY USE ONLY (Leave blank)	2. REPORT DATE	3. REPORT TYPE AND DATES COVERED
	December 1992	Final Oct 1990-Sept 1992

4. TITLE AND SUBTITLE
DATA ACQUISITION SYSTEM FOR ANALYSIS OF BURN INJURIES FROM FLAME AND THERMAL RADIATION

5. FUNDING NUMBERS
PE: 62786
PR: 1L1AH98
TA: CAB00
AG: TB1257

6. AUTHOR(S)
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7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
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Kansas Street attn: STRNC-UE
Natick, MA 01760

8. PERFORMING ORGANIZATION REPORT NUMBER
NATICK/TR-93/010

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)

10. SPONSORING/MONITORING AGENCY REPORT NUMBER

11. SUPPLEMENTARY NOTES

12a. DISTRIBUTION AVAILABILITY STATEMENT
Approved for public release, distribution unlimited

12b. DISTRIBUTION CODE

13. ABSTRACT *(Maximum 200 words)*
An advanced thermal response data acquisition system has been custom designed and built by Natick to provide state-of-the-art collection and analysis of the extent of burns induced by both flames and thermal energy transport through clothing systems. Data can be recorded in a laboratory setting or sent for miles on a single coaxial cable, fiber optic cable or FM frequency. A total of 521 sensors (124 on each of four manikins and 25 variably located) provide a temperature-versus-time record of the temperatures reached in the skin tissue of a hypothetical wearer of the clothing system. The researcher acquires data to be displayed in real time or stored for analysis of burn-severity predictions at any convenient future time. The data recorded from the experiments are used to generate two- and three-dimensional representations of the extent of skin burns predicted from skin simulant recordings. This system is a complete package, which gives researchers the tools required to study accurately and comprehensively the effects of flame and thermal radiation on wearers of military and/or civilian clothing.

14. SUBJECT TERMS

BURNS(INJURIES)	FLAMES	THERMAL RADIATION
THERMAL RESPONSE	MANIKINS	DATA ACQUISITION
MILITARY UNIFORMS	DATA ANALYSIS	

15. NUMBER OF PAGES 17

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
UNCLASSIFIED	UNCLASSIFIED	UNCLASSIFIED	

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PREFACE

This work was conducted to advance the state-of-the-art in the collection and analysis of data on the response of materials and military uniform systems to thermal energy insults. The data acquisition and analysis system described in this report will provide researchers with the capability to perform experiments in this field in a wider variety of environments than is now possible and enable them to use more fully the information gathered.

The research was performed under the Thermal Response of Uniforms to Thermonuclear Threat Program, Program Element 62786, Project 1L1AH98, Task CABOO, administered by the Fiber & Polymer Science Division, Soldier Science Directorate, U.S. Army Natick RD&E Center (Natick), during FY91-92.

The electronics hardware incorporated into this system was largely designed by Mr. Norman Porier of Northeastern University, Boston, MA. We wish to thank him for his efforts.

DATA ACQUISITION SYSTEM FOR ANALYSIS OF BURN INJURIES FROM FLAME AND THERMAL RADIATION

1.0 INTRODUCTION

The threat of burn injuries to military personnel arises from many sources. Fuel fires within or around combat vehicles, incendiary weapons, and flames resulting from exposure to thermal radiation from lasers or nuclear weapons pose hazards on the modern battlefield. The ability to predict the degree of injury each of these threats would inflict is vital for mission planners, uniform systems developers, and medical resources planning.

The development of simulants that mimic the response of human skin tissue was undertaken to find a substitute for using animal tissue in thermal injury studies (refs. 1-4). A measure of tissue damage (and, by implication, burn severity) can be achieved by knowing the increase in temperature at the dermis-epidermis boundary (approximately 80 μm beneath the skin surface) as a function of time. The omega value, Ω, is an index which was developed by Henriques (ref. 5) to indicate the severity of a skin burn. A value of omega greater than or equal to 1.0 indicates complete destruction of the epidermis.

Thermosetting resins with fillers forming a material that had the same thermal response characteristics as human skin tissue were developed by Derksen et al., at the Naval Material Laboratory (NML) (ref. 4). A mixture of urea-formaldehyde and silica, compression molded into a disc with a thermocouple embedded beneath the surface, was the result of this work. A manikin having a network of 124 sensors that were similar in design to the NML sensors was constructed by the Air Force in the early 1970's and used primarily for determining the flame protection provided by military flight suits. This system has been modified and extended by the Army and is now used not only for evaluation of skin and clothing burns from fires, but from lasers and nuclear-thermal radiation as well.

2.0 EQUIPMENT AND TEST METHODOLOGY

The manikin and sensor system outlined briefly above has been substantially expanded and upgraded. The present system used at the U.S. Army Natick Research, Development and Engineering Center (Natick) is known by the acronym ATRES/DAAS (ref. 6). The acronym stands for the Advanced Thermal RESponse Data Acquisition and Analysis System.

The system consists of four manikins each containing 124 skin simulant sensors. An additional 25 sensors may be used with the system and configured as needed. The sensors have been improved by substituting thermistors for the thermocouples previously used. Thermistors provide a greater output voltage, which reduces the effect of noise in the signal. Output from the sensors is fed to a data formatter and acquistion control unit located in the chest cavity of each manikin. A central controller and storage unit collects this information from each manikin and relays it to a personal computer for analysis and presentation (Fig. 1). The computer can receive the data either over a single coaxial cable or by an FM radio signal.

The exposure of the manikins to a source of flame or other thermal radiation varies with the characteristics of the source. In the past, fuel fire experiments were conducted in an outdoor flame-pit. A conflagration was started in a large area and the manikin, mounted on a boom, was swung through the flames. Today, environmental considerations dictate that an indoor fire be used to control the effluent emissions. Such a fire may be either in an open area or inside a mock-up of a combat vehicle or shelter. Nuclear-thermal radiation insults to uniform systems are conducted with a Thermal Radiation Source (TRS). The TRS utilizes the energy released from the highly exothermic reaction that occurs when aluminum powder is oxidized. The reaction generates a column of flames approximately eight feet high and three feet wide at a temperature of about 2900 K. The fluence at the surface of the target is determined by varying the burn time and the distance to the target.

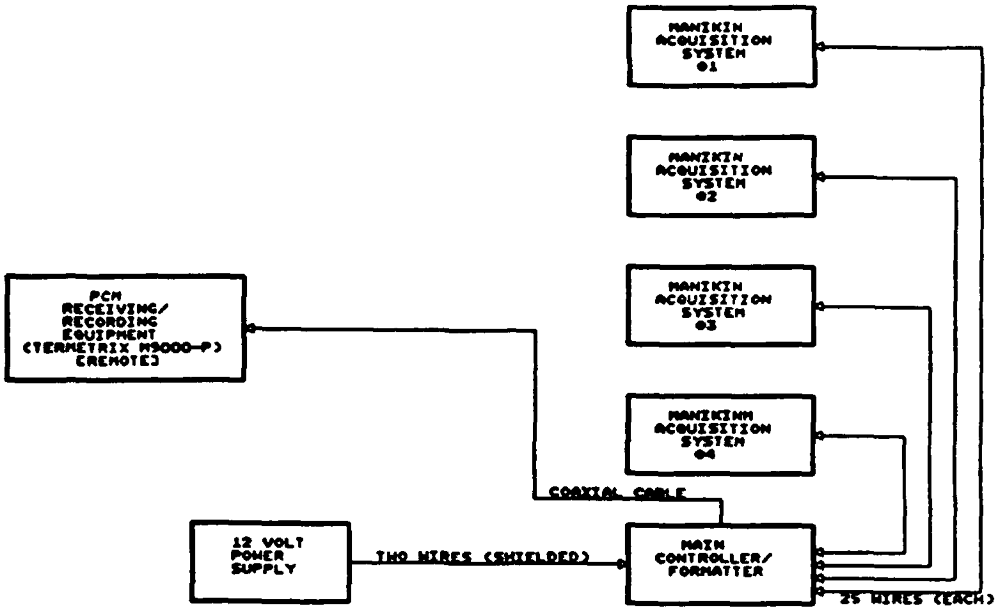

Figure 1. Schematic of the ATRES/DAAS.

Though cooler than the thermal radiation from an actual nuclear detonation, this system is currently the best way to irradiate targets as large as a manikin. The large area irradiated by the TRS allows all four manikins to be targeted simultaneously.

Data collection and recording begin one second prior to irradiation and continue for eight seconds subsequent to the removal from (in the case of fuel fires) or the extinguishment of (when using the TRS) the source. Thermistor voltages from the sensors are read 20 times each second from the 124 locations on each manikin. The raw data are stored on floppy disks for later processing.

Upon completion of the experiment the voltages from a thermistor are converted to temperatures, the temperatures are numerically integrated with respect to time, and an assessment of skin-burn severity is made.

This process is repeated for each of the 496 sensors. The skin-burn results are summarized for each manikin. The printout contains the burn damage sustained by each body area (arms, legs, and torso) as well as an overall burn-injury evaluation. These data are supplemented with two- and three-dimensional views of the manikin displaying the burned regions color-coded to the severity of the burn. The three-dimensional image is composed of 16 separate, contoured sections (some required subsections to be constructed first) based on measurements taken from the actual manikin (Fig. 2). Sensor representations (Fig. 3), which have been previously formed by locating the centerpoint of the sensor on the manikin image and intersecting a cylindrical solid with the surface of the image (centered on the sensor location), are then projected onto the manikin image.

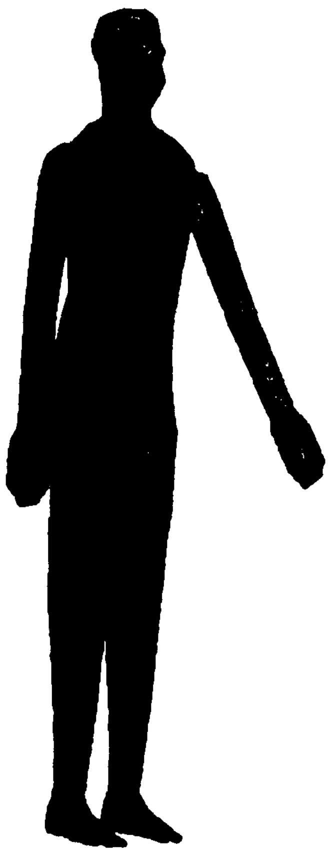

Figure 2. 3D manikin image.

Figure 3. A representative sensor area.

3.0 DATA PRESENTATION

The data collected during an experiment using the ATRES/DAAS may be presented for the researcher in four different ways. A table of the final omega values obtained at each sensor allows an evaluation of the operational status of each sensor during the test and a quantitative assessment of the omegas. A quantitative evaluation of the overall burn injuries which would have occurred is presented in tabular form (Fig. 4). This printout provides a record of the burn incidence by manikin body regions as well as by the manikin as a whole. A visual representation of the manikin areas sustaining burns can be generated on-site. This is a two-dimensional outline of the manikin with dark circles drawn to locate skin burns as indicated by the sensors (Fig. 5). Upon returning from the test site, researchers can generate three-dimensional views of the manikin using a SUN-3/60 computer (Fig. 6). These views enhance the analysis of the burn damage by eliminating the foreshortening that occurs when a circular area is viewed from an angle. Taken together, the data provide the foundation for a comprehensive analysis of the thermal protection afforded by the clothing or uniform system under investigation

```
Today's date is: 08-09-1990
Experiment name: CALIBRATION (10 cal/cm2)
Experiment date:  2-16-1990
```

```
% of SENSOR area with 2nd degree burns or greater

WHOLE BODY:  51.2
                 FRONT:   72.6      BACK:   30.8

HANDS:  96.1
        FRONT:   96.0       BACK:  96.2
        RIGHT:   92.2       LEFT: 100.0
    RF:  92.0    RB:   92.3   LF: 100.0    LB: 100.0

ARMS:  57.4
       FRONT:   76.2   BACK:   40.8
       RIGHT:   56.3   LEFT:   58.5
   RF:  75.7    RB:   37.4   LF:   76.7    LB:   44.0

LEGS:  31.5
       FRONT:   46.0   BACK:   14.9
       RIGHT:   15.9   LEFT:   47.2
   RF:  29.5    RB:    0.0   LF:   62.6    LB:   29.7

TORSO:  64.4
        FRONT: 100.0   BACK:   35.2
```

```
% of BODY area with 2nd degree burns or greater

WHOLE BODY:  45.2
                 FRONT:   62.6      BACK:   27.8

HANDS:  89.5
        FRONT:   89.5      BACK:   89.5
        RIGHT:   85.8      LEFT:   93.3
    RF:  85.8    RB:   85.8   LF:   93.3    LB:   93.3

ARMS:  47.5
       FRONT:   59.1   BACK:   36.0
       RIGHT:   46.5   LEFT:   48.6
   RF:  61.5    RB:   31.4   LF:   56.6    LB:   40.6

LEGS:  29.9
       FRONT:   44.0   BACK:   14.0
       RIGHT:   15.0   LEFT:   44.7
   RF:  28.3    RB:    0.0   LF:   59.8    LB:   27.9

TORSO:  55.3
        FRONT:   81.8   BACK:   31.6
```

Figure 4. Quantitative body-region analysis output.

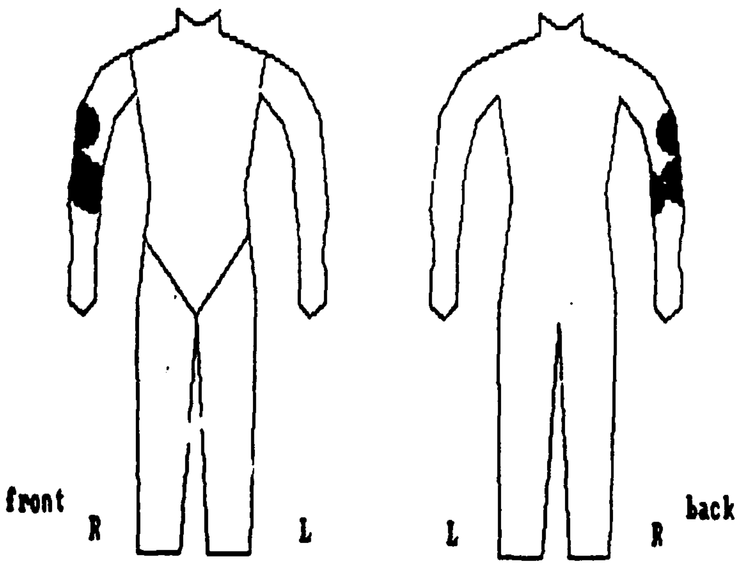

Figure 5. 2D graphics output showing skin burns.

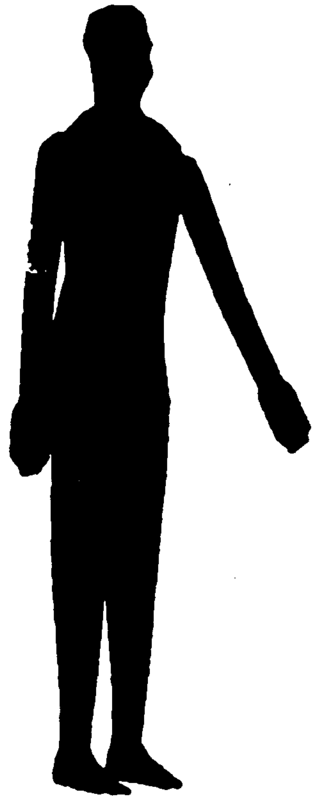

Figure 6. 3D graphics output.

4.0 FUTURE WORK

Modifications to the ATRES/DAAS are planned, which will expand the versatility of the system. The first of these modifications will be to make the computer codes controlling the burn-injuries statistics and manikin graphical representations compatible with the outputs of mathematical models of thermal energy transport through materials. This would enhance the usefulness of these models. Next, adaptation of the graphics package will be initiated to allow computer-aided design (CAD) models of personal equipment to be incorporated with the manikin image. Combined images of figure and equipment will allow analysis of the impact on thermal transfer of the placement of such items as pockets and fasteners. The current list of upgrades entails the outfitting of the manikins with flexible joints. Articulated manikins placed inside mock-ups of vehicle passenger compartments can provide a more realistic look at potential injuries in closed environments.

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